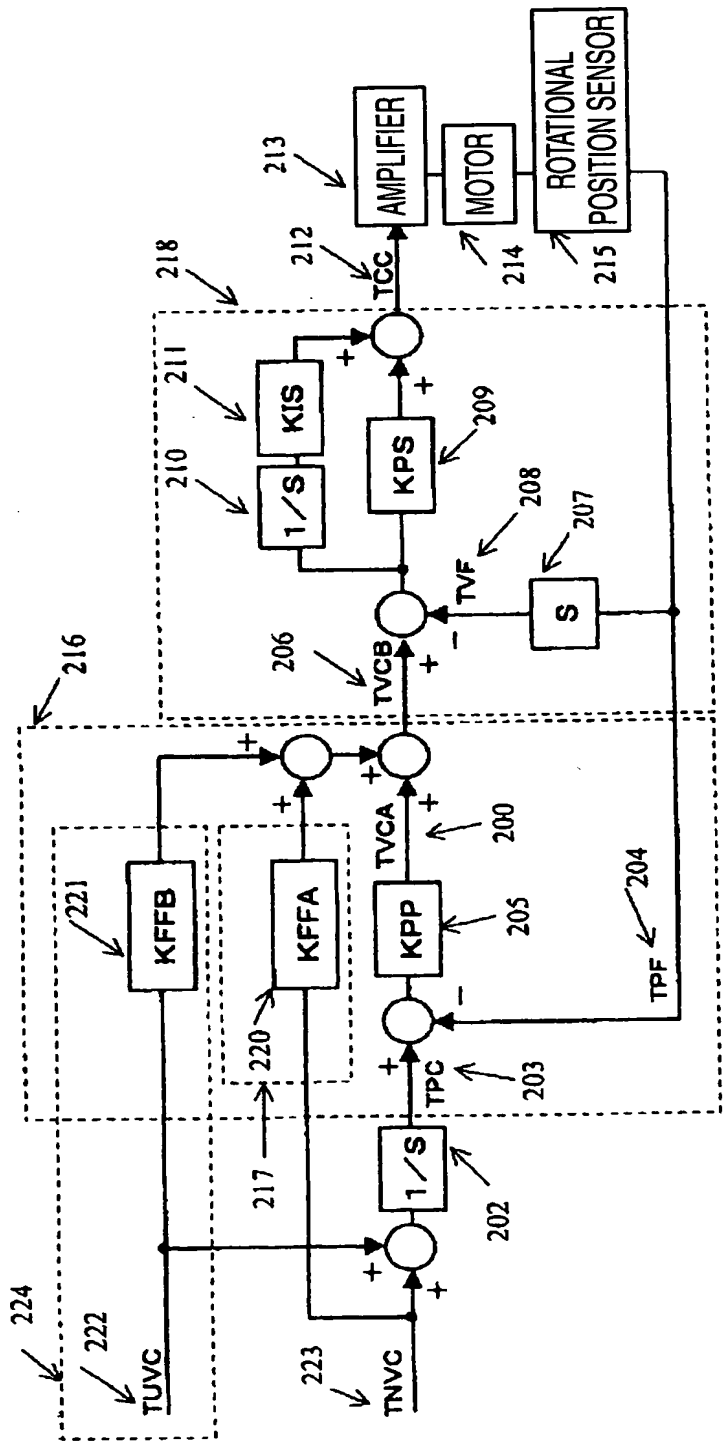


FIG. 1



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FIG. 2

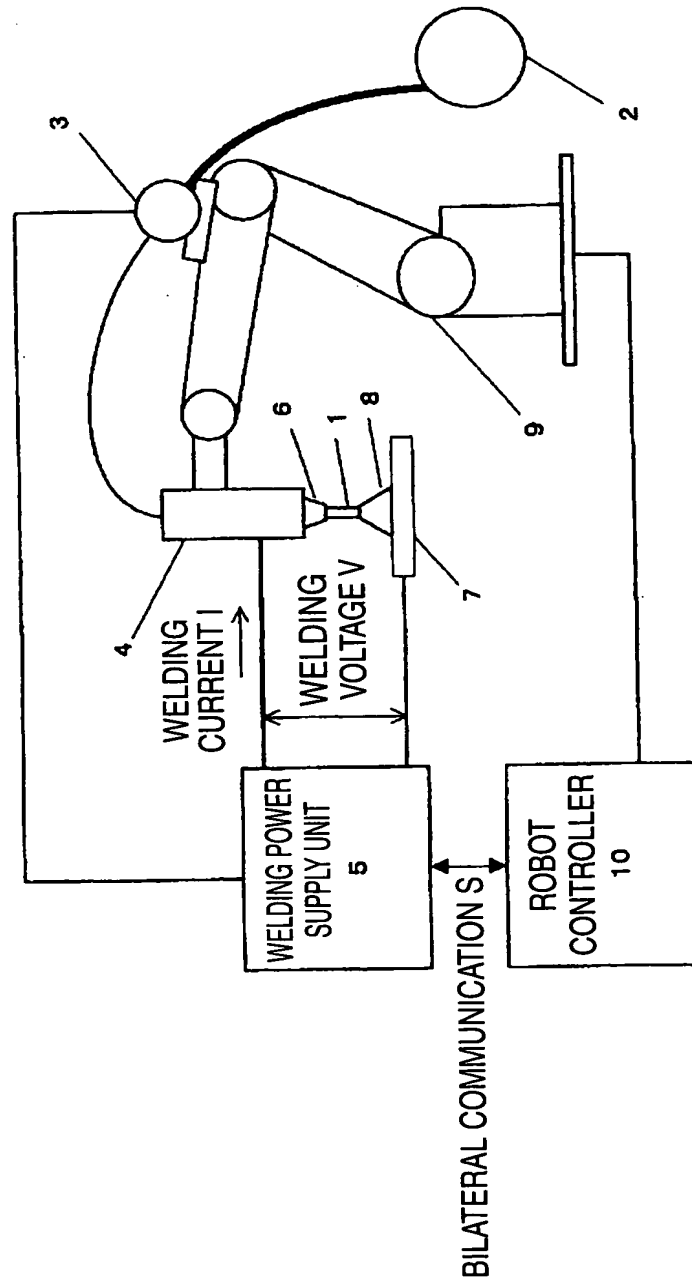


FIG. 3

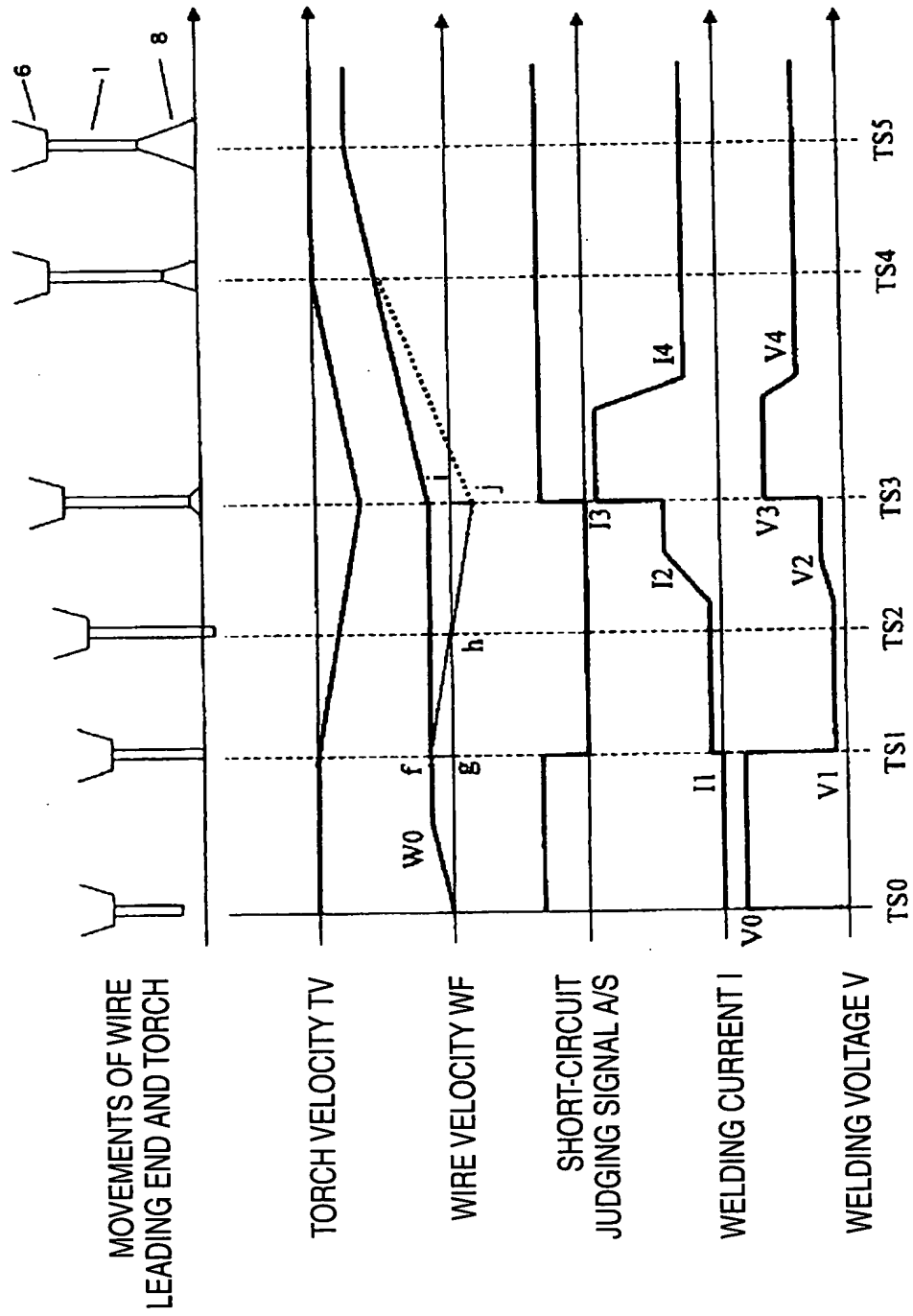


FIG. 5

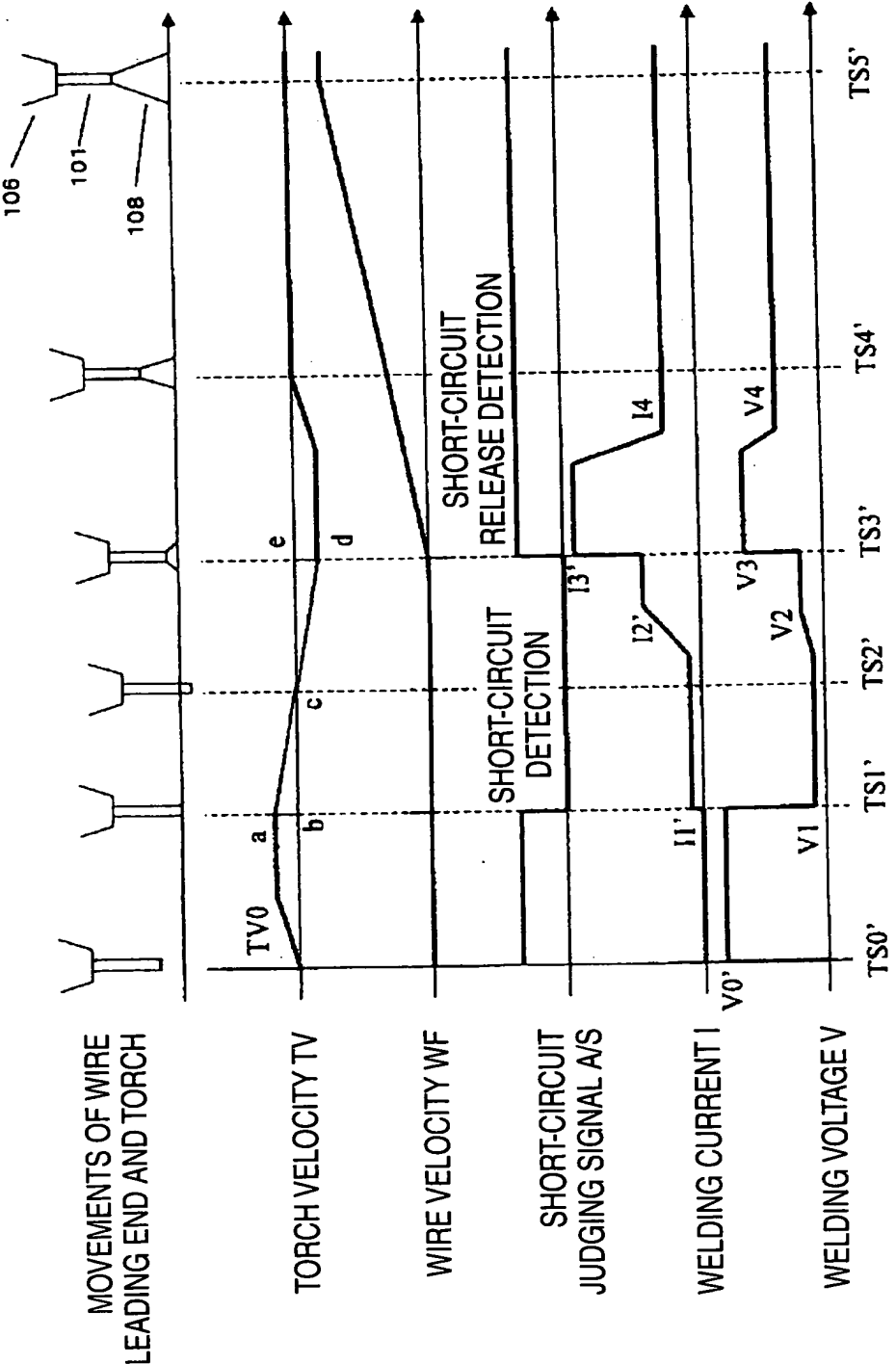
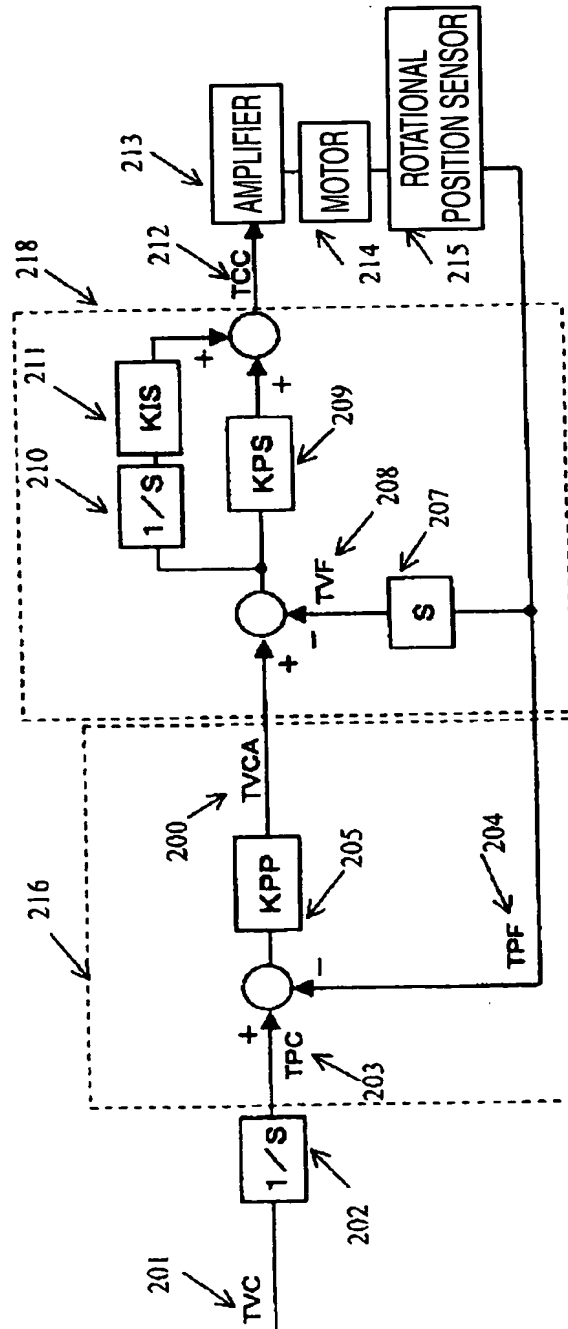


FIG. 6



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FIG. 7 (a)

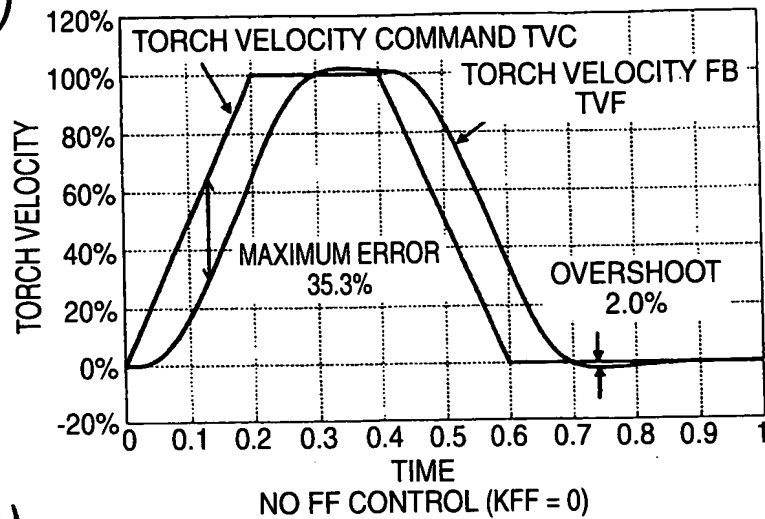


FIG. 7 (b)

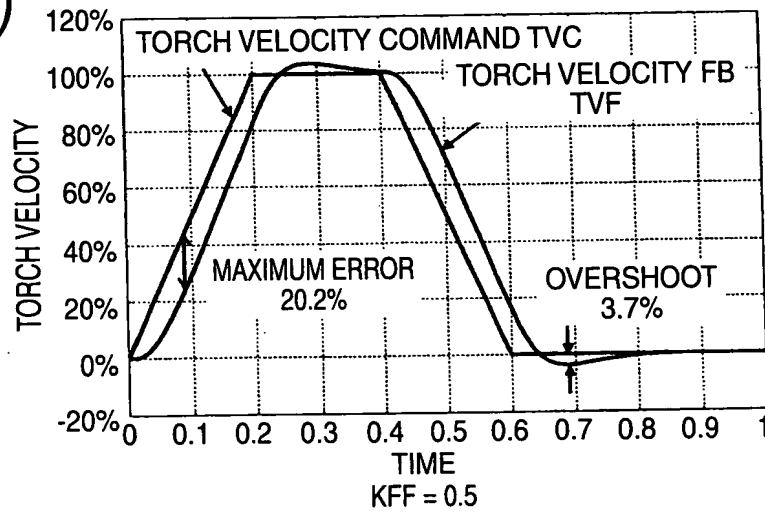
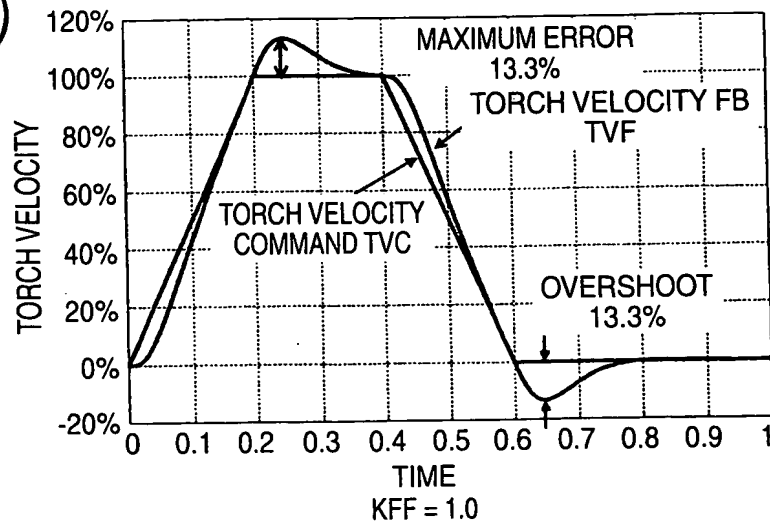


FIG. 7 (c)



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FIG. 8 (a)

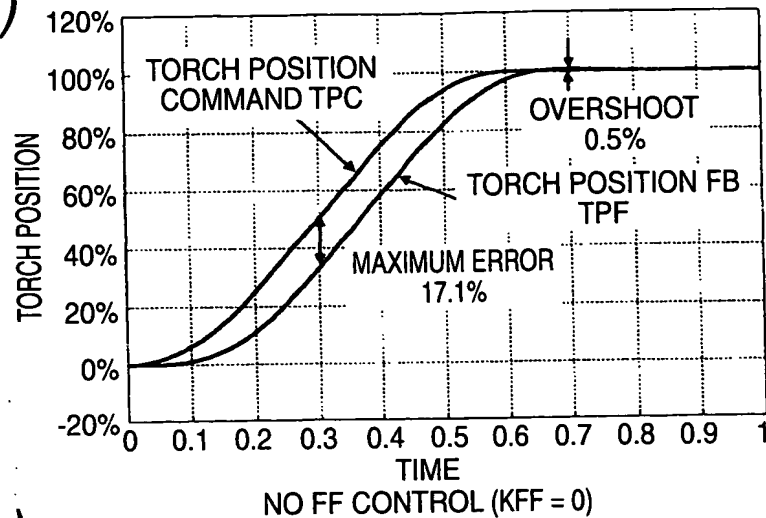


FIG. 8 (b)

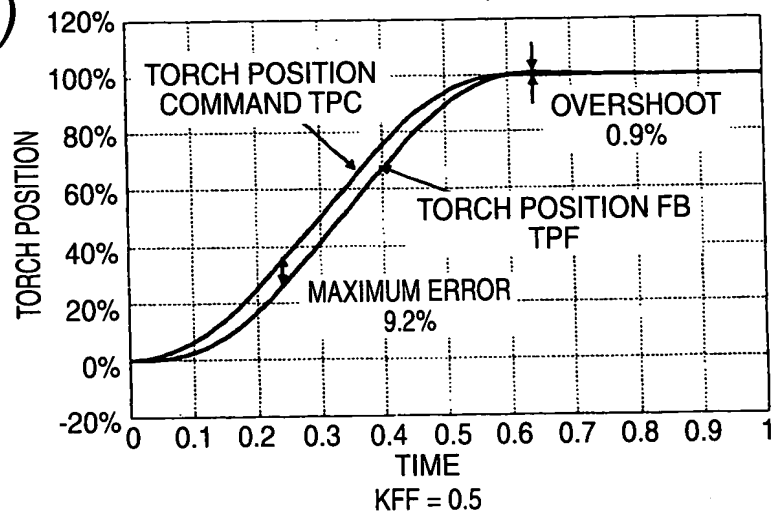


FIG. 8 (c)

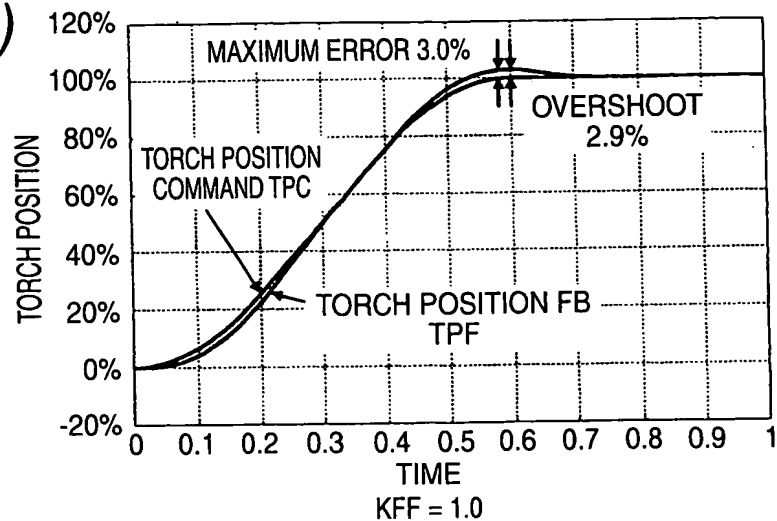
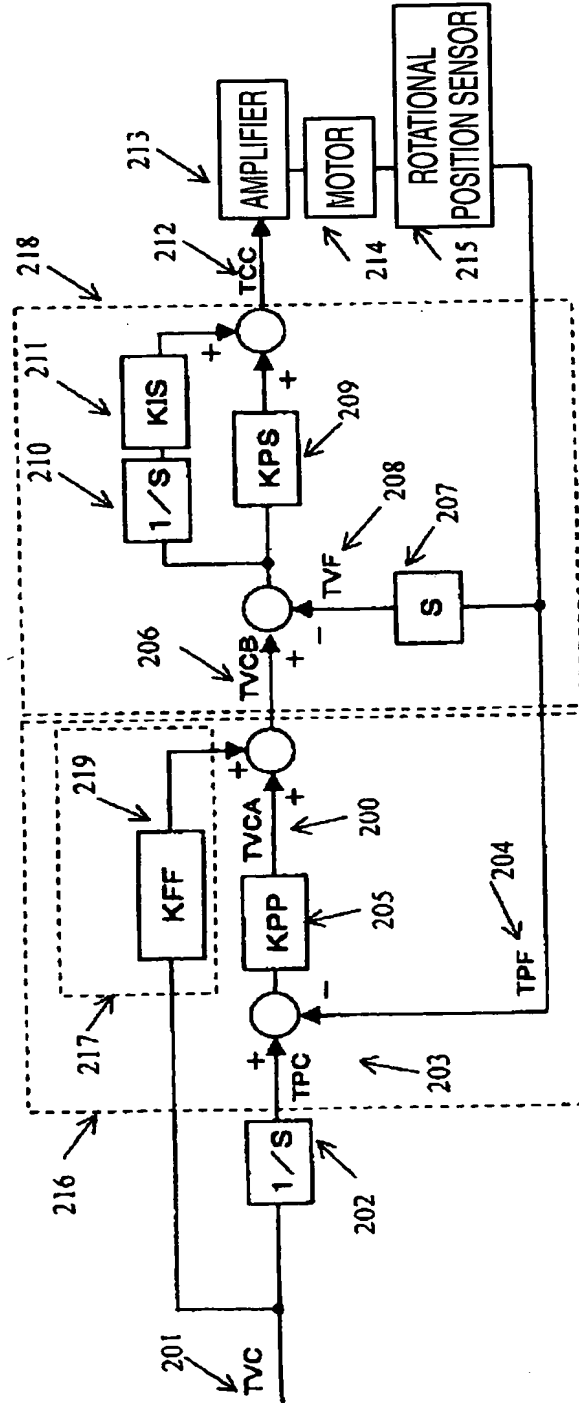


FIG. 9



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FIG. 10 (a)

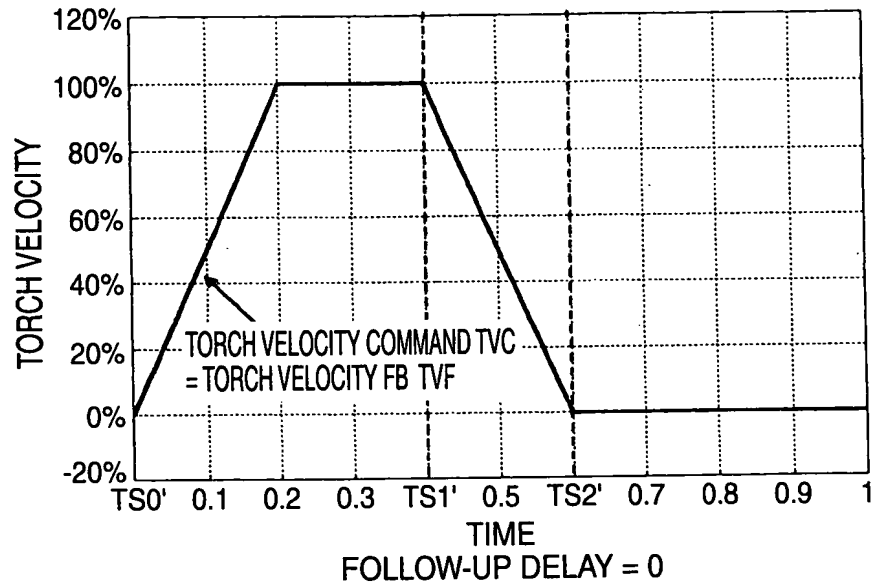
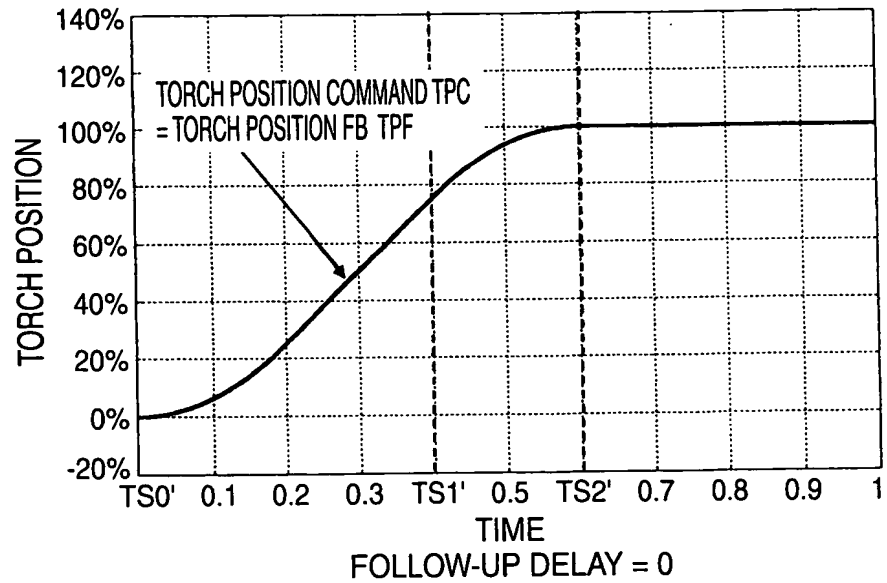


FIG. 10 (b)



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FIG. 11 (a)

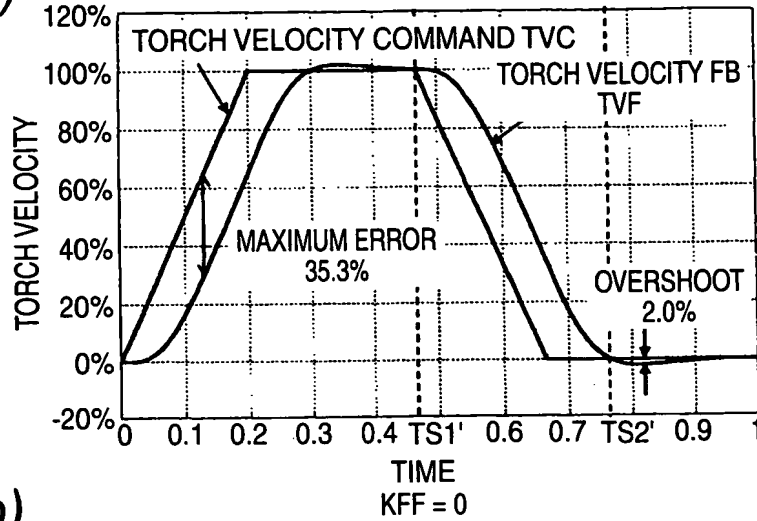


FIG. 11 (b)

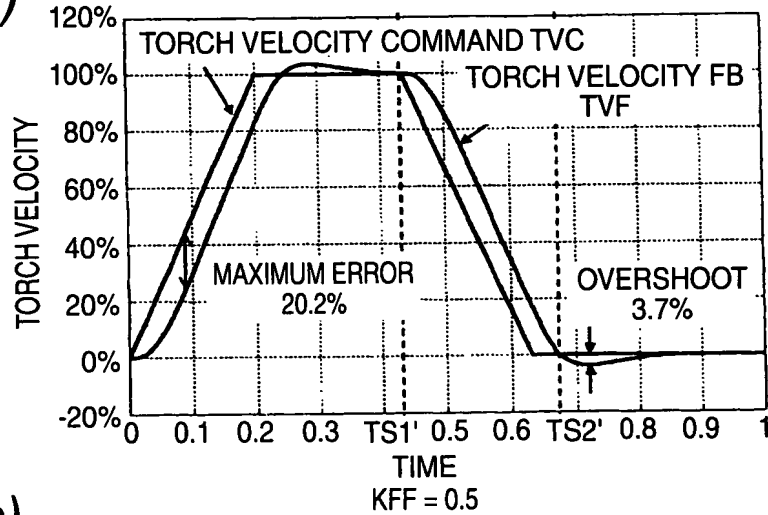
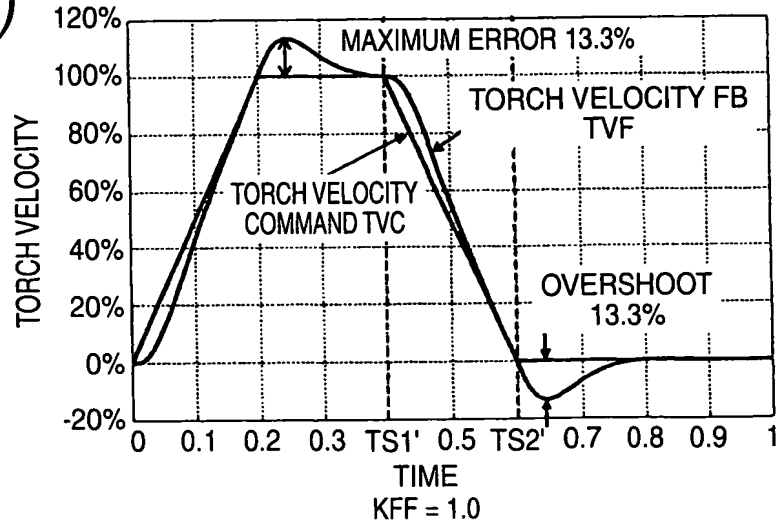


FIG. 11 (c)



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FIG. 12 (a)

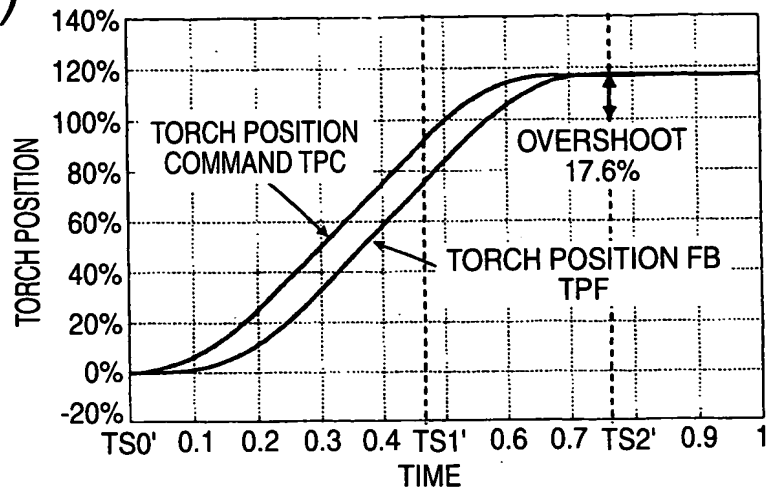


FIG. 12 (b)

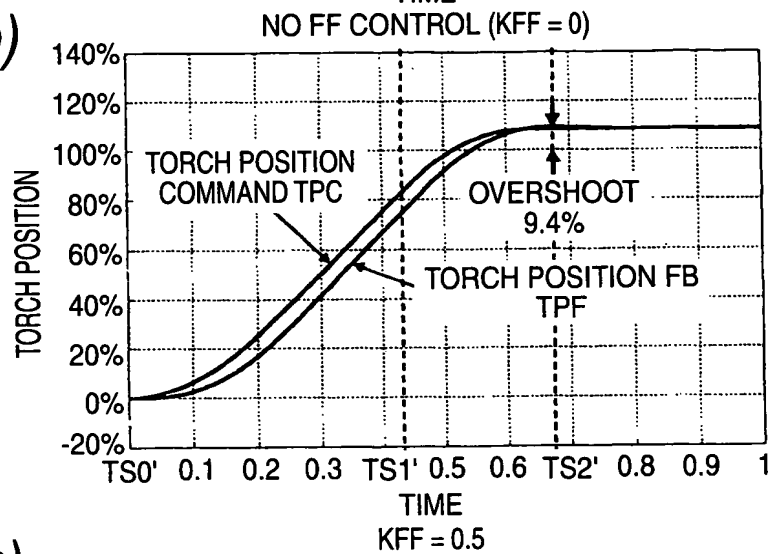
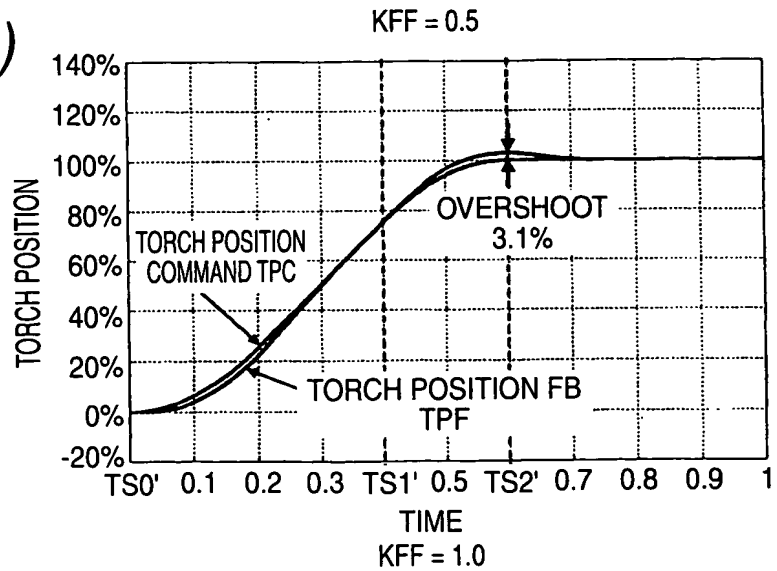


FIG. 12 (c)



The diagram illustrates a control system for a robot arm, organized into several functional blocks and feedback loops:

- Position and Velocity Feedback (Left Section):**
 - Input $d\theta_{com}$ (1) is integrated ($1/s$, block 3) to produce θ_{com} (5).
 - θ_{com} (5) is compared with feedback θ_M (4) at summing junction 6.
 - The error signal is processed by a PID controller (block 8) with proportional gain K_P and integral gain K_I/s .
 - The output of the PID controller is compared with feedback ω_{com} (7) at summing junction 9.
 - The resulting error signal is integrated ($1/s$, block 10) to produce the reference velocity ω_m (11).
- Velocity and Torque Control (Middle Section):**
 - ω_m (11) is compared with feedback ω_m (2) at summing junction 12.
 - The error signal is processed by a torque controller (block 13) with gain K_t .
 - The output is compared with feedback τ_m (14) at summing junction 15.
 - The resulting error signal is integrated ($1/(J_m \cdot s + D)$, block 16) to produce the reference torque τ_{dis} (17).
- Collision Detection and Control (Right Section):**
 - The reference torque τ_{dis} (17) is compared with feedback τ_{dyn} (18) at summing junction 19.
 - The output is processed by a dynamic model ($J_m \cdot s + D$, block 20) to produce the reference velocity ω_{com} (21).
 - ω_{com} (21) is compared with feedback ω_{com} (22) at summing junction 23.
 - The error signal is processed by a gain K_μ (block 24) to produce $\tau_{\mu 0}$ (25).
 - $\tau_{\mu 0}$ (25) is compared with feedback τ_{dyn} (26) at summing junction 27.
 - The resulting error signal is integrated ($1/(J_m \cdot s + D)$, block 28) to produce the reference torque τ_{iso} (29).
- Collision Detection Logic (Bottom Section):**
 - The reference torque τ_{iso} (29) is compared with feedback τ_{dyn} (30) at summing junction 31.
 - The output is compared with a threshold τ_{vth} (32) at summing junction 33.
 - The resulting signal is processed by a block s (34) to produce α_{com} (35).
 - α_{com} (35) is compared with a threshold α_{com} (36) at summing junction 37.
 - The resulting signal is processed by a block s (38) to produce τ_{vth} (39).
 - τ_{vth} (39) is compared with a threshold τ_{vth} (40) at summing junction 41.
 - The resulting signal is processed by a block s (42) to produce τ_{vth} (43).
 - τ_{vth} (43) is compared with a threshold τ_{vth} (44) at summing junction 45.
 - The resulting signal is processed by a block s (46) to produce τ_{vth} (47).
 - τ_{vth} (47) is compared with a threshold τ_{vth} (48) at summing junction 49.
 - The resulting signal is processed by a block s (50) to produce τ_{vth} (51).

The diagram illustrates a control system for a two-axis robot arm, organized into several functional blocks:

- Block 6 (Leftmost):** Contains a summing junction (3) and an integrator $\frac{1}{s}$ (40). It receives the reference position θ_{com} (1) and feedback position θ_M (4) to produce the error signal θ_{com} (3).
- Block 10 (Middle-Left):** Contains a summing junction (7) and a feedback path with a proportional gain K_P (8) and an integral gain $K_I \frac{1}{s}$ (9). It receives the error signal (3) and the motor position θ_M (4) to produce the command velocity ω_{com} (7).
- Block 18 (Top):** Contains a summing junction (12) and a feedback path with a gain K_t (12). It receives the command velocity (7) and the motor velocity ω_M (11) to produce the error velocity τ_m (13).
- Block 16 (Bottom):** Contains a summing junction (14) and a feedback path with a gain $\frac{1}{J_m \cdot s + D}$ (17). It receives the error velocity (13) and the motor velocity ω_M (11) to produce the error torque τ_{dyn} (15).
- Block 20 (Right):** Contains a summing junction (19) and a feedback path with a gain $\frac{1}{J_m \cdot s + D}$ (21). It receives the error torque (15) and the motor velocity ω_M (11) to produce the error torque τ_{iso} (24).
- Block 26 (Far Right):** Contains a summing junction (22) and a feedback path with a gain K_μ (23). It receives the error torque (24) and the motor velocity ω_M (11) to produce the error torque τ_{dyno} (29).
- Block 27 (Bottom Right):** A "JUDGMENT OF COLLISION" block that receives the error torque τ_{iso} (24) and outputs a signal to the "JUDGMENT OF DIRECTION" block (22).
- Block 25 (Top Right):** A "JUDGMENT OF DIRECTION" block that receives the error torque τ_{iso} (24) and outputs a signal to the "KINETIC TORQUE CALCULATION" block (26).
- Block 28 (Middle Right):** A "KINETIC TORQUE CALCULATION" block that receives the error torque τ_{iso} (24) and outputs a signal to the "JUDGMENT OF COLLISION" block (27).
- Block 30 (Far Right):** A "JUDGMENT OF COLLISION" block that receives the error torque τ_{iso} (24) and outputs a signal to the "JUDGMENT OF DIRECTION" block (22).
- Block 31 (Bottom Right):** A "JUDGMENT OF COLLISION" block that receives the error torque τ_{iso} (24) and outputs a signal to the "JUDGMENT OF DIRECTION" block (22).

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FIG. 15

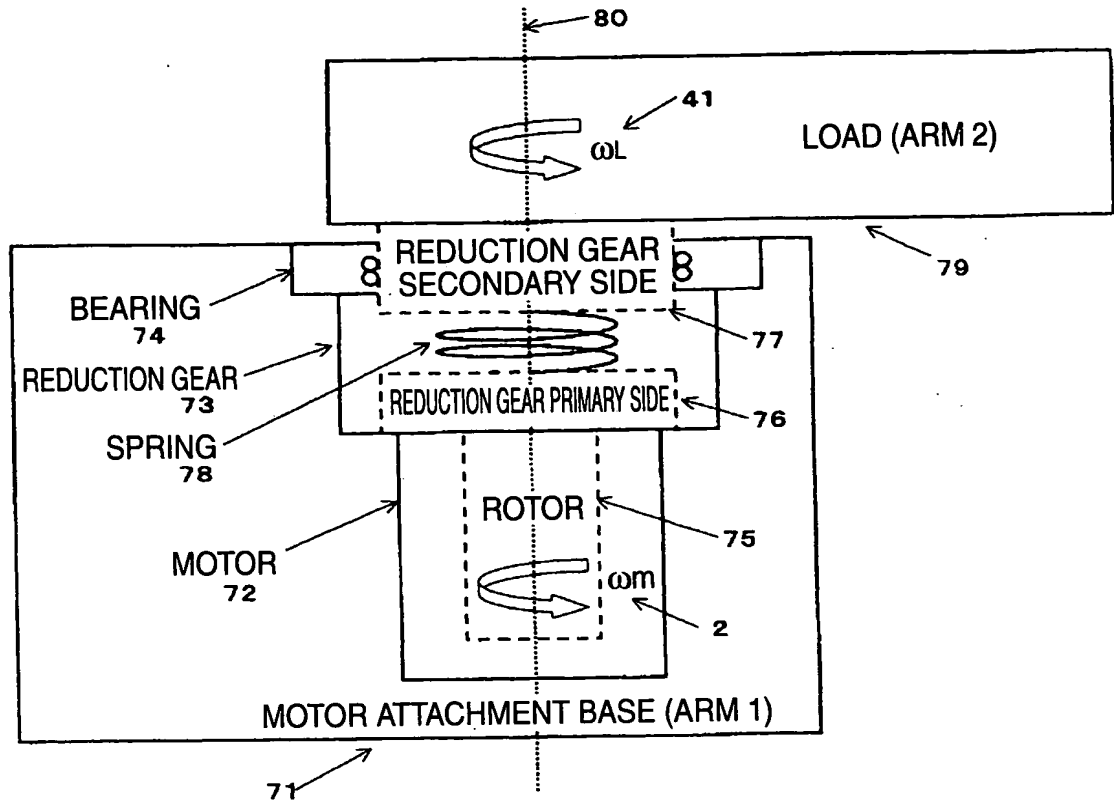
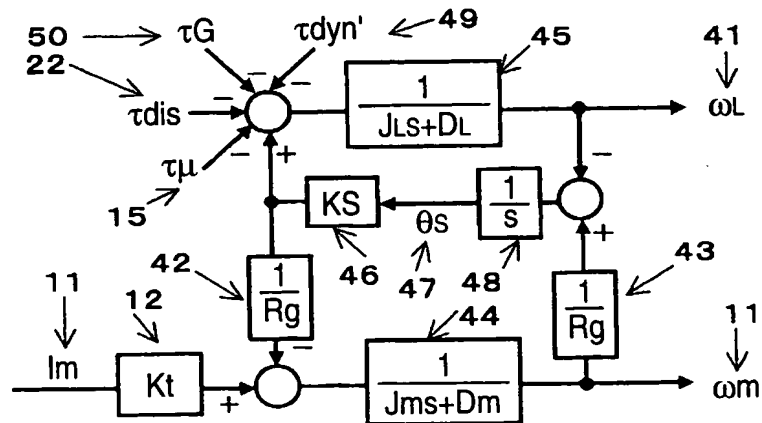


FIG. 16



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FIG. 17

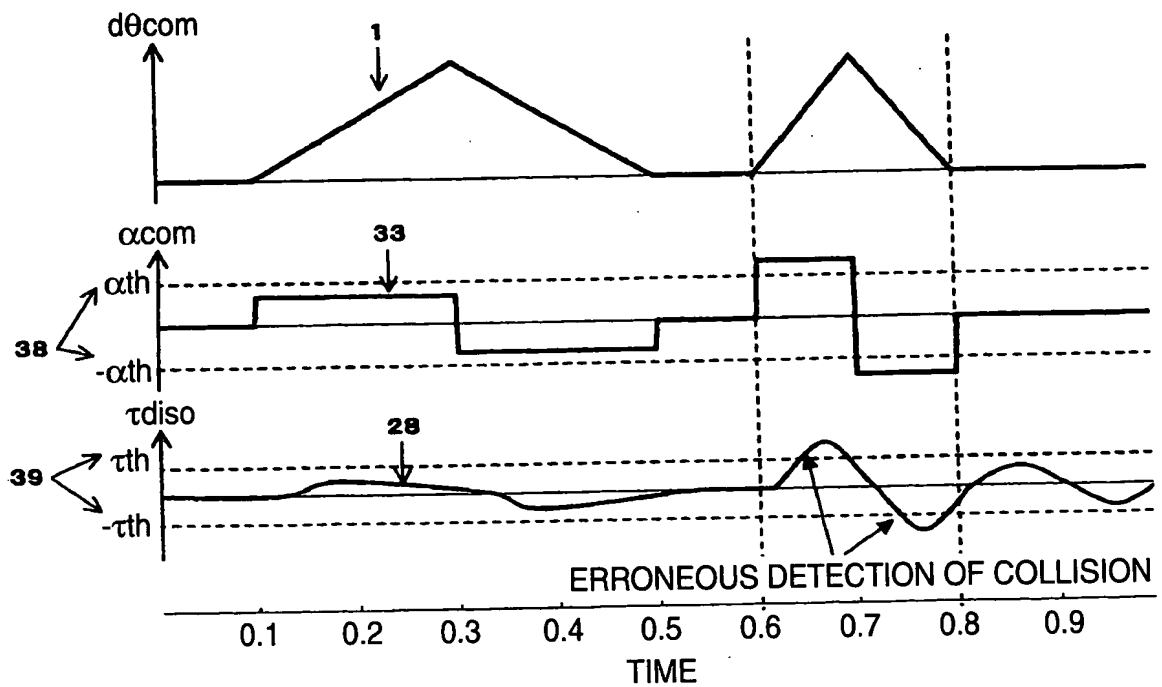


FIG. 18

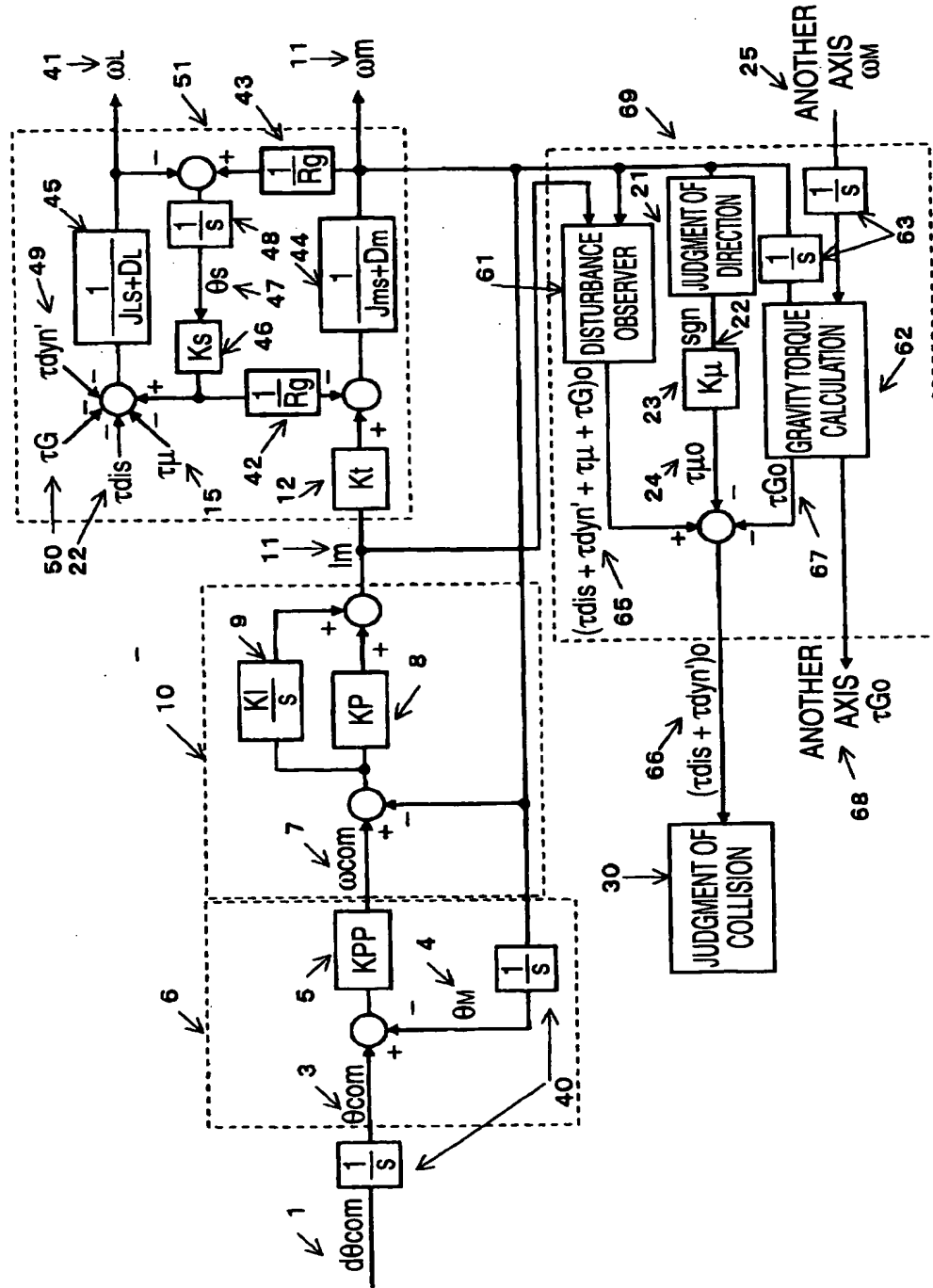


FIG. 19

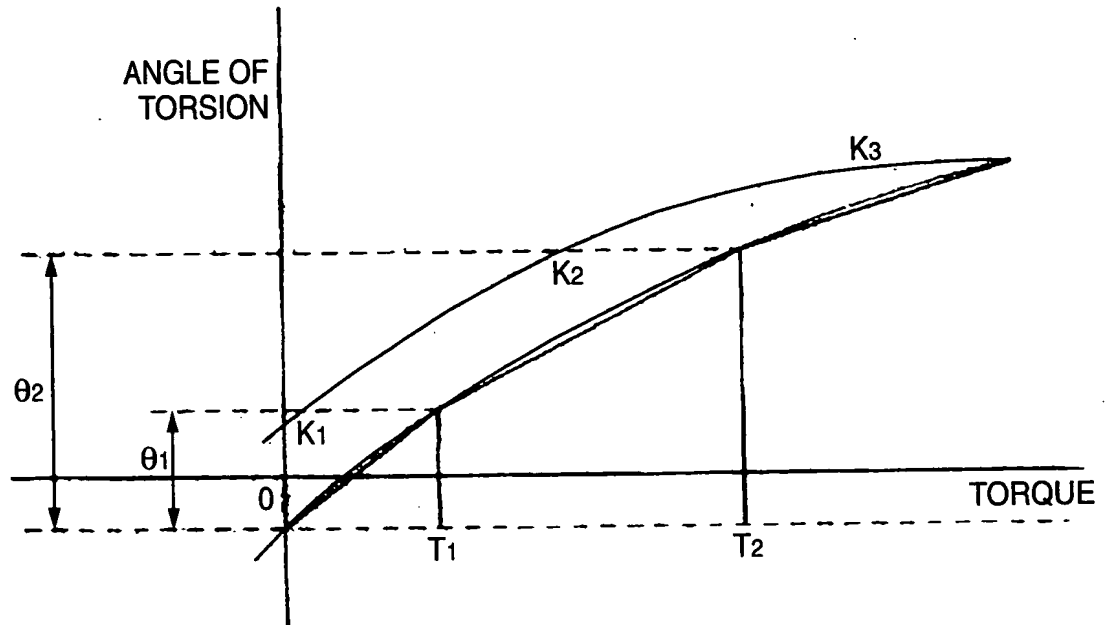
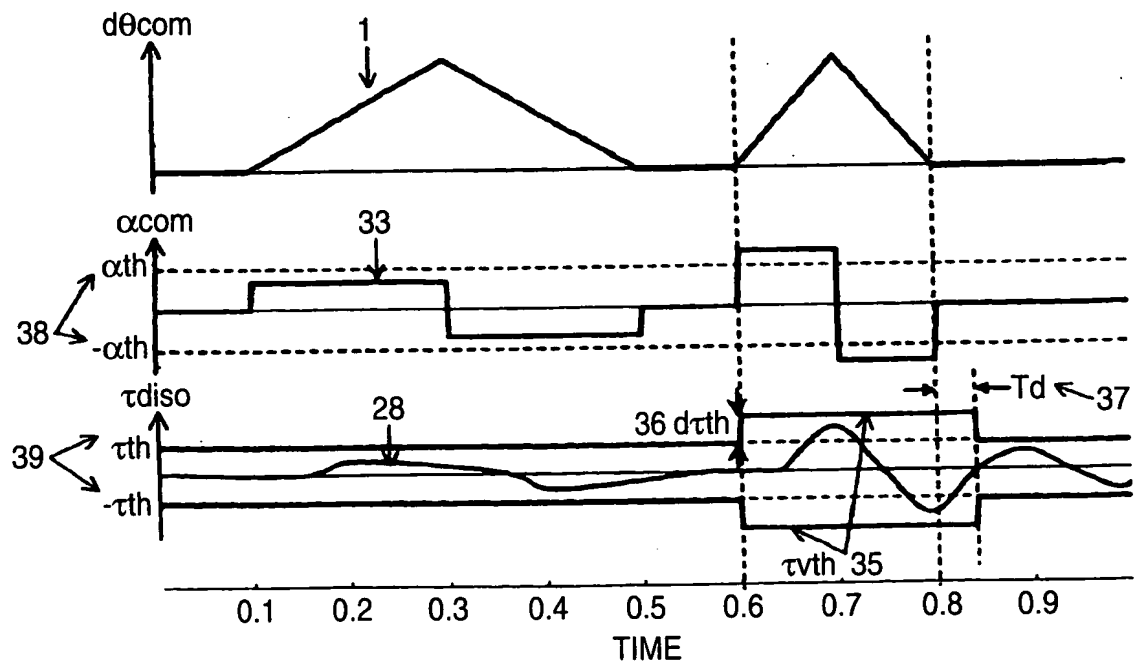


FIG. 20



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FIG. 21

